

# BOP Art



## The Art of Mounting Blast Overpressure (BOP) Transducers

W. Scott Walton  
Ballistic Technology Officer  
US Army Test Center  
Aberdeen Proving Ground, MD

Aberdeen Test Center

## BOP Measurement Missions

A pressure measurement technician's nightmare! (0.03 psi vs. 20,000 psi)

- **Measure many different types of pressure:**
  - Quasi-static pressure for structural effects
  - High level pressure for lethality
  - BTD pressure for survivability
  - Low level side-on pressure for training safety
  - Side-on, Face-on, Stagnation, etc.
- **Armored Vehicle Testing**
  - Crew Compartment (Human)
  - Ammunition Compartment (structural)
- **Weapon Testing (Human)**
  - Crew Area
  - Instructor/Observer Areas (140 dB)
- **Combat Ship Testing**
  - Magazine Compartments (Structural)
  - Crew Compartments (Human)
- **Aircraft Testing for Passenger and Cargo Compartments (Structural & Human)**
- **Ammunition/Warhead Testing**
  - Stun Grenade (Hostage/Terrorist)
  - Bunker Defeat (Lethality & Structural)
  - Wall Breaching (Lethality, Structural, Human)



**THE ART OF BOP MEASUREMENT**

Objective	Issues	Tools
Know the Objective!	Training vs. Combat, Structure or Human	MIL-STD 1474, 'INJURY' Model, Structure Model
Know the Enemy	Side-on, Face-on, Stagnation, Quasi-Static	Orientation, Mount Geometry
Expect the Unexpected	Heat, Acceleration, Reflections, Fragments	Soft Mount, Thermal Shield, Frag. Pole
Check Instrumentation	Compromises, Range Reflections, Function	Shock Tube, Arena, 'Pinger'
Keep Score During The Test	All of the above, plus those you forgot!	Blind gages, data fusion & cross check

**BOP Measurement of Small Arms & 140dB (0.03 psi) Limit for Hearing Protection (Instructors & Observers)**



## Measurement of BOP in Crew Area of Large Caliber Weapons



## Combat & Structural BOP Missions



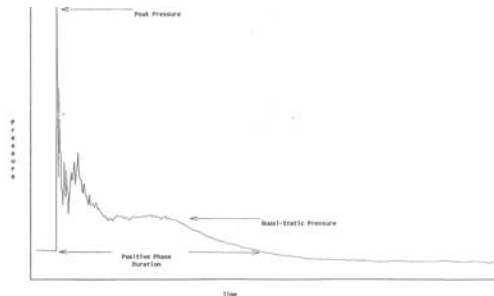
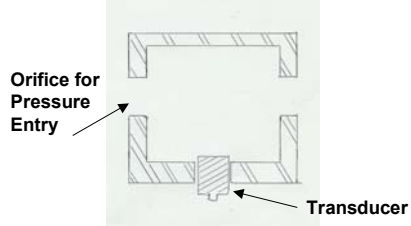
- Vehicle Attack
- Ammunition Magazine Explosion
- Bunker Attack
- Wall Breaching in Urban Combat

# Quasi-Static Pressure Measurement

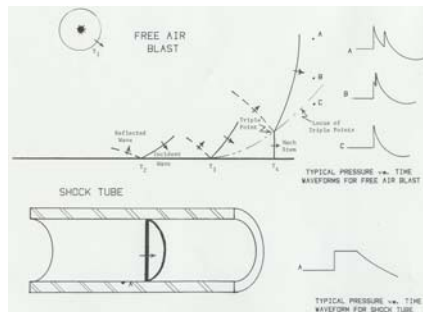
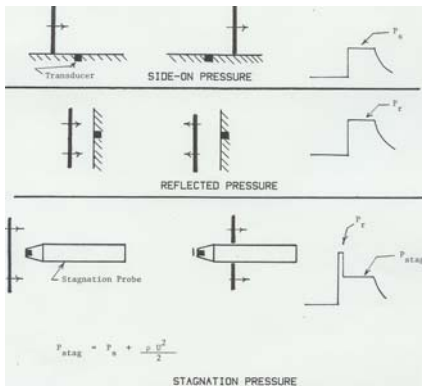


- Microsecond Shock Waves Too Fast for Millisecond Structural Response
- Need a mount to keep out shock waves so a low pressure quasi-static transducer can be used

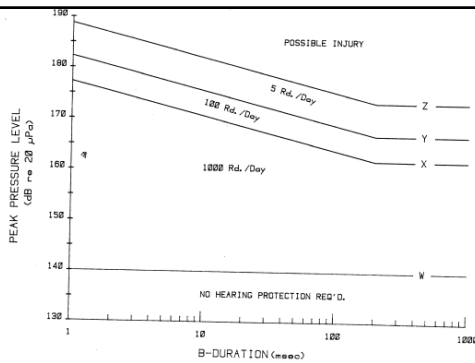
Quasi-Static Transducer Mount



## Know the Enemy (and do the math!)



Reflected pressure is at least 2X higher than side-on pressure



## Training Criteria

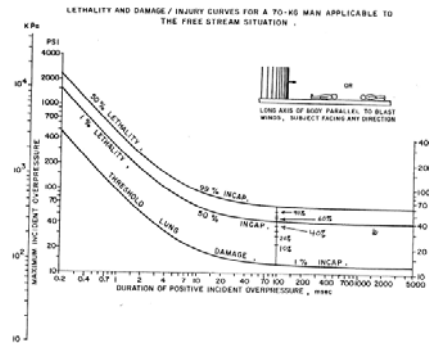
MIL STD 1474 for Hearing Protection (0.03 – 10 psi)

## Survivability Criteria

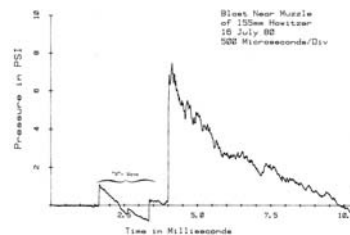
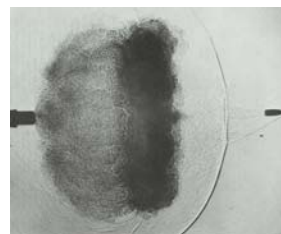
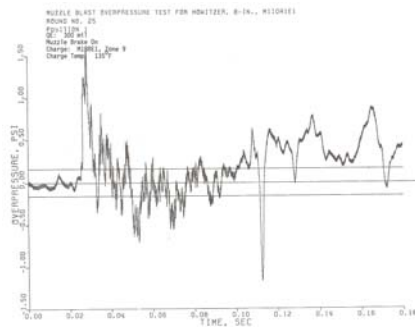
WRAIR INJURY Code 7.3

(BOP/HHA)

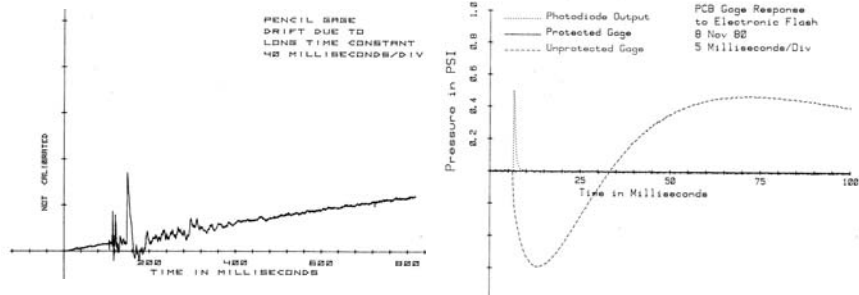
(10 – 100 psi)



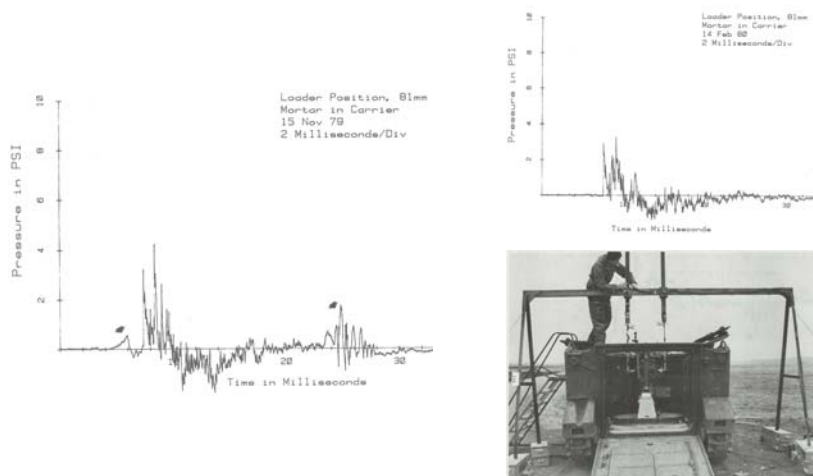
## Extraneous Effects



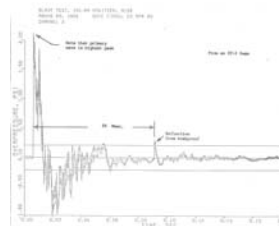
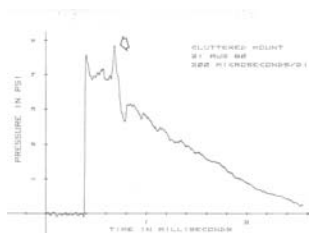
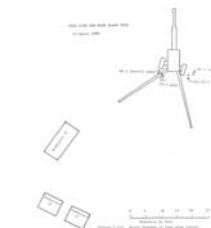
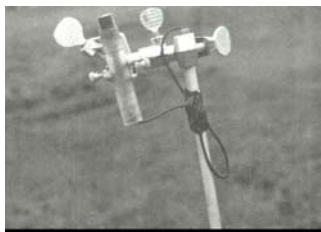
# Thermal Protection



# Acceleration Isolation



# Reflections



## Pressure Transducers

Piezoresistive, piezoelectric, PVDF foil, Carbon 'Flatpack'

**Need to measure very high pressures (10,000 psi) to support hydrocode modeling**

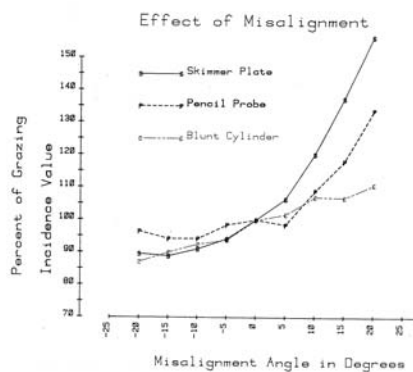
## Transducer Mounts

For Side-On Pressure, Peak Reflected Pressure, and Quasi-Static Pressure

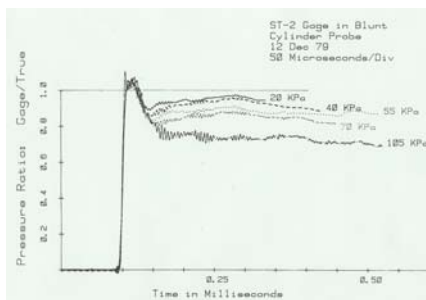
Mount design techniques contributed by Navy, ARL, ERDC, Sweden, UK, etc. Shock tube technique most robust in high fragmentation environment.



# Alignment Issues



## Rewards and Penalties for Various Mount Geometries



Blunt Cylinder Overshoot & Undershoot (Good Off-Axis, Good MILS-STD 1474, Bad for High Pressure CFD Modeling)

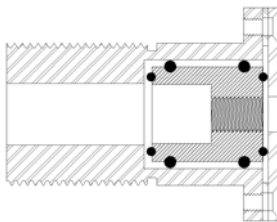
Pencil & Skimmer Plate do not overshoot (But poor off-axis)

Skimmer plate is omni-directional in 1 plane (But very bad out of plane)

# Small Transducers and Human Size Mounting



## Blast Overpressure Measurement



### Measurement Considerations:

- Protect PE & PR Transducers from Heat, Light, Acceleration, and Fragments
- Smooth Aerodynamic Shape for Peak Pressure
- Protect Quasi-Static Gages from Peak Shock Waves
- Mount transducers in 'Blast Test Device' (BTD) for evaluation using WRAIR "INJURY" Code
- Limited Success with PVDF, Carbon, & Ytterbium sensors for close-in blast measurement

## Arena Test to Verify Transducer Performance (or 'Range Calibration Shot' to Evaluate Reflection Effects)



## Wall Breaching Test Setup

Fragment Hazards, Fragment Collection, Behind  
Armor Debris Evaluation, and other Objectives  
Conflict with BOP Objectives



**How seriously are the BOP measurements compromised??**

## Conclusions

- There is always some art hidden deep within the science!
- Many Compromises (Aerodynamic Cleanliness, Directionality, Fragment Protection, Shock Isolation, etc.)
- Use Blind Transducers, Check Channels, Data Fusion, and Arena Testing to Verify Compromises